# INVESTIGATION OF DIMENSIONS OF PERCEPTION OF UNITED STATES SENATORS ON DEFENSE-ORIENTED ROLL-CALL VOTES

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## Monterey, California

# THESIS

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September 1973



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# Investigation of Dimensions of Perception of United States Senators on Defense-oriented Roll-call Votes

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Submitted in partial fulfillment of the
requirements for the degree of

Master of Science in Operations Research

from the

NAVAL POSTGRADUATE SCHOOL
September 1973

ABSTRACT

A somewhat new approach to the analysis of defense issues in the United States Senate has been developed in this thesis. The Relative Agreement statistic of Brams and O'Leary was used to obtain similarity observations between twenty Senate defense votes for both 1969-1970 and 1971. These similarity observations were then used as input data to KYST, a multi-dimensional scaling computer program. The scaling solutions resulting from KYST showed that the most important dimensions in explaining pro-defense voting were non-partisan/partisan and foreign policy/domestic policy. By using the pro-defense proportion of the vote as the dependent variable and coordinates from the two-dimensional solution as the independent variables, a regression model was obtained for predicting pro-defense vote. Within the time period under consideration, an examination of regression coefficients revealed that future arguments for defense programs in the Senate should emphasize foreign policy and non-partisan aspects of such programs while de-emphasizing domestic implications and partisan aspects.

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# I. INTRODUCTION

Collective decision-making has become a fertile field for analysis in the past twenty years although study in this area began long before that. Legislative roll-call analysis has its origins around the beginning of this century when A. Lawrence Lowell, a historian and president of Harvard University, began such studies. Lowell published "The Influence of Party Upon Legislation in England and America" in 1901. He tried to show the effect of membership in a political party on the voting behavior of legislators in the United States and Great Britain using roll-call data [Ref. 2]. In 1928, an American writer of great influence in this field, Stuart Rice, produced Quantitative Methods in Politics in which he discussed quantitative analytic methods for studying roll-call votes. Anderson, Watts and Wilcox in Legislative Roll-call Analysis [Ref. 2], a well-known source on methods for analysis of roll-call data, state that there was not much work done with roll-call votes from the time Rice published his work until after World War II. They hypothesize that there are several reasons for the increased interest in roll-call analysis in recent years. First, trends among political scientists have been a major contributing factor. More emphasis has been placed on research in the area of individual actions in political institutions rather than in the study of the institutions exclusive of the individuals within them. In

addition, recent trends have tended to reflect a belief that political scientists should analyze political affairs with a view to rendering an accounting of public policy. Not only have these trends developed, but a move toward more quantitative analysis has also manifested itself, and roll-call data is certainly quantitative in nature. Second, the development of new techniques such as Guttman scale analysis and factor analysis has accelerated the use of roll-call data. Third, and perhaps most significant in the view of the author of this thesis, is the development of high-speed computers which enable analysts to perform tasks which were formerly impossible, or so complicated that for practical purposes they were impossible. In fact, Carl F. Kossack [Ref. 21] has stated the following amazing fact, ". . . in some respects whatever data processing was evolved in the 1940's can now be done a million times faster."!

One of the studies conducted in the late nineteen-forties was "Consistency of Voting by Our Congressmen" by Dean R. Brimhall and Arthur S. Otis [Ref. 5]. This is an interesting investigation of roll-call data but one of little application today. However, it might be useful to discuss it briefly. Brimhall and Otis took ratings by New Republic Magazine on the votes of 512 Congressmen to look at "consistency" in voting. A separate analysis was accomplished for Senators and Representatives. If New Republic gave a voter a plus (+) on a given roll-call, his vote was considered "progressive." A minus (-) was considered "anti-progressive." A

zero indicated the voter was absent or paired. Using these ratings, the authors determined the percentage of the time each legislator voted "progressively" as viewed by New Republic. For example, if a voter were present and voting for ten votes and cast eight "progressive" votes, his percentage was 80%. They then divided the list of Senators (or Representatives) into sevenths on the basis of "progressiveness" percentages. The top seventh was given a score of one which indicated the most "progressive," or liberal. The next seventh, was scored with a two, and so on down the line until a seven was given to the bottom seventh, which consisted of the most "anti-progressive," or conservative, Senators (or Representatives). This procedure was followed for roll-call votes during a four year period. After aggregating the data for Senators and Representatives, Brimhall and Otis found that 46% of the Congressmen did not change their scale values from one year to the next, 83% did not change more than one unit from year to year, and 95% did not change more than two units on the rating scale from year to year. These figures indicate a very high degree of consistency of voting among Congressmen. The result is not altogether unexpected since the time period, four years, is a relatively short one to expect an individual's viewpoint to change radically. However, the method of achieving the result by using roll-call data is quite interesting, and rather innovative to have been written twenty-five years ago. The authors themselves said that they believed their work to

be the first study of consistency in voting among members of Congress.

Shortly after the Brimhall-Otis study appeared, Duncan MacRae, Jr. began his pioneering work on the Massachusetts House of Representatives. MacRae was particularly interested in the interaction between the legislator and his district. In Ref. 27, he examined two variables, "per cent owner occupancy of dwelling units" in the legislator's district and the margin of election victory over his opponent. MacRae used these two variables as a basis for drawing inferences from roll-call votes in three sessions of the Massachusetts House. The "per cent owner occupancy of dwelling units" variable had a tendency to differentiate between Republican and Democratic districts. There was a higher percentage of owner occupancy in primarily Republican districts and he found that there appeared to be a relatively distinct cutoff on each end of the scale so that Republican districts tended to be high and Democratic districts were low. However, there was a middle ground of significant overlap. Interestingly enough, the closely contested seats (defined by a winning margin of less than 60% of the two-party vote) were overwhelmingly found to be in the overlap region for owner occupancy. After examining roll call votes, MacRae found that representatives coming from districts typical of their party tended to be most loyal to the party on roll calls and that those representatives coming from districts where their election was close tended to reflect the characteristics of

their constituency more than those whose elections were not close. He recommended that anyone desiring to influence a legislator to cross party lines might be more successful if he chose one coming from a district which was not typical of his party. He also felt that it might be somewhat easier to convince a representative to vote contrary to his constituency if that representative came from a district where he had a large victory margin in the previous election. This article might well be considered a landmark study of the impact of socio-economic factors on the votes of legislators.

In a later article [Ref. 28], MacRae delved deeper into the relationship between the security of a legislator's position; i.e., years of continuous service and previous electoral margins of victory, and his voting habits. To accomplish this, he constructed a Guttman scale of liberalism and conservatism for the 1951-52 session of the Massachusetts House, and examined the occupations of members when the legislature was not in session. MacRae also looked at the effect of national and state elections on the local elections of representatives. He found that there was some influence of races for Governor, President, and so forth, on the election of legislators in their districts but there was also a tendency for legislators to be able to "buck the tide" if they had more seniority. MacRae also noted that those with more seniority had a tendency "to run farther ahead of their state tickets" than junior legislators. He attributed some of this result to their votes on the "liberalism-conservatism

dimension." He also felt that senior members tended to be more like professional politicians and exhibited greater loyalty to party leaders.

Moving ahead a few years to look at another analysis of roll-call data, one finds "The Analysis of Bloc Voting in the General Assembly: A Critique and a Proposal" by Arend Lijphart [Ref. 26]. The author looked at 44 roll-call votes on the issues of colonialism from 1956 to 1958 in the United Nations General Assembly. Lijphart used an Index of Agreement proposed by Stuart Rice and Herman Beyle to examine coalitions in the General Assembly and attempt to determine how cohesive these blocs of votes were. While this study is somewhat more sophisticated in terms of technique and objectives than that of Brimhall and Otis and the early MacRae studies, it still does not fully utilize the power of an electronic computer.

Only two years later, Hayward Alker and Bruce Russett [Ref. 1] examined four different UN General Assembly sessions using factor analysis, a statistical technique borrowed by social scientists from psychologists. The object of the Russett-Alker study was the isolation of issues and alignments, or blocs, in the four sessions. Thus, this investigation might be viewed as an expanded version of Lijphart's study having similar objectives, although still more sophisticated methods were used.

Then, in 1968, Duncan MacRae, Jr. and Susan Schwarz [Ref. 30] used cluster analysis, factor analysis, and

multidimensional scaling to investigate the votes of Republican Congressmen in the 1955 and 1956 sessions of Congress. The primary objective of the study was a comparison of various techniques that could be used to identify issues as perceived by Congressmen. This study would not have been feasible without the use of an electronic computer.

The preceding very sketchy review of the literature on roll-call analysis for the past twenty-five years obviously does not do justice to the many scholars in the field. An example is Duncan MacRae, Jr. who has, according to Anderson, et al, "pioneered the development of roll-call analysis in recent years" [Ref. 2, p. 119]. However the object was not to conduct a complete survey of the literature but to indicate the trends in roll-call analysis. It is clear that a revolution of sorts has occurred if one looks at the Brimhall-Otis study of 1948 and compares it to the MacRae-Schwarz study of 1968.

By way of review, then, it appears that three distinct trends have developed in the analysis of roll-call votes in the last twenty-five years. First, those social scientists studying voting bodies have begun to examine the effects of political actors in their institutions in a more quantitative manner as in Brimhall-Otis, the early MacRae studies, and the Lijphart U.N. analysis, and have begun to try to render an accounting of public policy by identifying policy issues as in the Alker-Russett and MacRae-Schwarz studies. Second, Guttman scaling, factor analysis, and to some extent, multi-

dimensional scaling, are new techniques that have been chosen to facilitate roll-call analysis. Third, the development of the high-speed electronic computer has been indispensible to the analyst seriously attempting to examine voting bodies by quantitative methods.

## A. THE IMPORTANCE OF ROLL-CALL ANALYSIS

"Congressional Government is Committee Government," thought Woodrow Wilson in 1884 [Ref. 41]. In 1962, Heinz Eulau said [Ref. 17]

> Whether, in fact, the roll call is the most important step in the legislative process--an implicit assumption, certainly in many roll-call studies--is a matter of argument. By the time a bill comes up for final action, it has been scrutinized, debated, and amended in committee or on the floor, if not compromised in the cloak room. The final vote may conceal more than it reveals.

If these statements be true, why study roll-call votes at all? Eulau himself provides a partial answer when he says [Ref. 17]

> Whether a bill finds unanimous support, is reluctantly accepted, or acrimoniously contested, just as the alignment of legislators along partisan, rural-urban, and other lines of cleavage, can tell us much about the functioning of the political system as a whole. Much important work has been done along these lines.

Thus, one can gain insight into the political process by studying roll calls. But beyond this, it would seem now to be possible to glean more information from these records, at least with regard to the United States Senate.

Much of the action on bills now occurs on the floor of the Senate in roll calls. Committees have not relinquished their power but Senators appear to no longer be reluctant to

offer amendments on the floor which run counter to the recommendations of the relevant committee. Consider the amendment by Senator George McGovern (D-S.D.) to amend HR8687, Military Procurement Authorization for Fiscal Year 1972, recommending that the President submit an alternate defense budget for Fiscal Year 1973 not to exceed $60 billion. The mere offering of such an amendment is astonishing, since Senator McGovern was not on the Armed Services Committee, but the fact that it received 31% of the vote on a roll call in the Senate would have been inconceivable only a few years prior to that time. Senator Strom Thurmond (R-S.C.) said of this amendment, "That such a proposal would even be made in the Congress will certainly send shock waves through our defense establishment and the confidence of our free world allies" [Ref. 10, p. 318]. Senator Thomas McIntyre (D-N.H.), a member of the Senate Armed Services Committee, stated, "There is no need for such drastic and ill-considered action with respect to the defense budget" [Ref. 10, p. 318]. It is interesting to note that when Senator John Stennis (D-Miss.), chairman of the Senate Armed Services Committee, introduced the above procurement bill, he felt that "This bill as reported outlines an austere and prudent program . . . which should be funded now" [Ref. 10, p. 316]. Yet an amendment gaining substantial support on the Senate floor was put forward requesting the President to submit an alternate proposal cutting 15% to 20% from the overall defense budget for the next year. This vote, and others like it, indicate

that, while committees still retain the reins of power in the Senate, a great deal of the action now occurs on the Senate floor.

Dr. Edward Laurance [Ref. 25] has hypothesized that this process began in 1967 and 1968, at least with regard to the defense budget, and Senatorial relationships reached the present degree of relative independence in the 91st Congress. Prior to this time, the Senate, and particularly the Armed Services Committee, was little more than a rubber stamp for the defense budget. However, that is no longer the case, and non-defense spending now competes on a co-equal footing with defense spending for tax dollars. This is due, in part, according to Dr. Laurance, to an increase in the power of the Senate Armed Services Committee, which can now successfully challenge the Defense Department on its budget requests, but also to a proliferation of expertise in defense and national security policy throughout the Senate. The latter cause has led to an increase in debate on these issues on the Senate floor and the offering of a greater number of amendments to defense bills.

According to Lawrence J. Korb [Ref. 20]

> Since the late 1960's, Congress has taken an increasingly larger role in the examination of the defense budget. . . . With increasing frequency floor fights over particular items have extended the legislative phase of the defense budgeting cycle halfway into the fiscal year. It appears that the days when Congress would approve $70 billion defense budgets in less than an hour are a thing of the past.

Table 1, taken directly from Korb's article, shows the seemingly sudden change in Congressional attitudes toward the defense budget beginning in 1969.

It is clear that 1969 represents a turning point in Congressional consideration of defense spending, since cuts have averaged $4.23 billion per year since 1969 and only $.476 billion for the period 1962-1968. This represents almost a tenfold increase in the amount of money cut from the budget each year, beginning in 1969.

There is an historical legislative basis for the recent increase in power of the Armed Services Committee. Section 412(b) of the Military Construction Authorization Act for Fiscal Year 1960 requires that [Ref. 14]

> No funds may be appropriated after December 31, 1960, to or for the use of any armed force of the United States for the procurement of aircraft, missiles, or naval vessals unless the appropriation of such funds has been authorized by legislation enacted after such date.

Prior to the enactment of this law, the only congressional contact with military weapons procurement or, indeed, overall defense policy came in the appropriations committees which were swamped with the sheer magnitude of this and other budgetary decisions. With the passage of this bill, the legislative committees; e.g., Armed Services, became involved in the matter of examining defense policy. Raymond Dawson of the University of North Carolina has stated [Ref. 14] that the Congressional role in defense policy-making has been expanded in three respects as a result of Section 412. First, Congressional access to the processes of policy formulation

TABLE 1

CONGRESSIONAL CHANGES IN DEFENSE BUDGET REQUESTS: FY 1962-1973

Source: Office of the Assistant Secretary of Defense (Comptroller)

| Fiscal Year | Congressional Change[1] | |
|---|---|---|
| | %[2] | Millions of dollars[2] |
| 1962 | +0.58 | + 268 |
| 1963 | +0.48 | + 230 |
| 1964 | -3.66 | - 1797 |
| 1965 | -1.51 | - 717 |
| 1966 | -0.18 | - 81 |
| 1967 | +0.70 | + 403 |
| 1968 | -2.30 | - 1638 |
| 1969 | -6.75 | - 5201 |
| 1970 | -7.49 | - 5638 |
| 1971 | -3.13 | - 2147 |
| 1972 | -4.02 | - 2951 |
| 1973 | -6.56 | - 5221 |
| Average change | -2.81 | - 2040 |
| Total change | | -24490 |
| Average absolute change | 3.10 | 2191 |

[1]Congress deals only with the new obligational authority (NOA) requests of the administration.

[2]Excludes funds for military construction, civil defense, military assistance, and AEC.

has been expanded. Second, Congress is now able to focus on specific areas of policy, rather than the overall defense budget in which major policy decisions may be buried. Third, the Congress' base of knowledge on defense issues has been expanded as a result of the first two improvements.

Dawson's analysis of the situation prior to Section 412 is corroborated by Lewis A. Dexter [Ref. 15], who conducted interviews with Congressmen during the period 1955-57. Dexter found the Congressmen were generally concerned with more mundane decisions such as manpower requirements rather than overall strategic policy decisions. Members of the House Armed Services Committee looked upon it as a "real estate committee," meaning that it was concerned only with location, sale, and transfer of defense installations.

Hence, with the passage of Section 412(b), the role of the Senate Armed Services Committee was strengthened and a greater base of knowledge was available to the Congress as a whole. The eight years may be what was required for the Armed Services Committees to develop the expertise in defense matters.

As a result of these developments, the years 1969 through 1971 were chosen for this analysis of defense issues since little information would be obtained by looking at defense roll-call votes prior to 1969.

In summary, despite Woodrow Wilson's famous comment on Congressional governmer , which is still largely true at least with regard to power in Congress, the study of defense

roll-call votes is considered interesting and profitable for the aforementioned reasons.

## B. OBJECTIVE OF THE PRESENT ANALYSIS

In the past few years, issues involving the armed forces and the Department of Defense (DOD) as well as the National Aeronautics and Space Administration (NASA) and the Atomic Energy Commission (AEC) have been subjected to increasing scrutiny by the United States Senate. In an era of shrinking funds for national defense and defense-related programs, decision-makers need to be aware of the manner in which Senators view bills in these areas. It was the rather ambitious objective of this analysis to examine Senate roll-call votes for the $91^{st}$ Congress and the first session of the $92^{nd}$ Congress to determine the dimensions of perception that Senators had for votes on defense-related issues during the period. Minor objectives were the determination of whether or not these dimensions remained the same from Congress to Congress and an attempt to relate these dimensions of perception to the outcomes of votes.

## C. OUTLINE OF PROCEDURE USED FOR THE ANALYSIS

To determine dimensionality, a relatively new technique called multidimensional scaling was employed. To use this method, it was necessary to obtain measures of similarity-dissimilarity between roll call votes. An index called Relative Agreement proposed by Steven Brams and Michael O'Leary [Ref. 3], which will be discussed later, was chosen

to obtain the comparisons. These measures were then used as input to a multidimensional scaling computer program called KYST [Ref. 24]. The results from KYST were examined to discover the number of dimensions that could best be used to explain the perceptions of Senators on the selected votes. Then, using multiple linear regression [Ref. 39], a model was formulated to explain pro-defense voting as a linear function of these dimensions.

## II. DISCUSSION OF MULTIDIMENSIONAL SCALING

J. B. Kruskal of Bell Telephone Laboratories has developed the basic procedure for multidimensional scaling which is used in the KYST computer program. In Refs. 22 and 23, Kruskal explains the algorithm he has conceived to accomplish this scaling. The procedure will be discussed in some detail below.

For an example of an application of multidimensional scaling, see Ref. 16 in which James Capra and Richard Elster examined the preferences of U.S. Naval officers at the Naval Postgraduate School for selected public personalities to serve as President of the United States. They were able to obtain a reasonable two-dimensional solution for these preferences.

### A. BASIC CONCEPTS OF MULTIDIMENSIONAL SCALING

#### 1. Monotonicity

The underlying concept of multidimensional scaling, as described by Kruskal, is monotonicity. In Ref. 22, he states

> The problem of multidimensional scaling, broadly stated, is to find n points whose interpoint distances match in some sense the experimental dissimilarities of n objects. . . . What is essential is that we desire a monotone relationship, either ascending or descending, between the experimental measurements and distances in the configuration.

Thus, one wishes to obtain a configuration of n points which have interpoint distances that correspond to the

experimental dissimilarity observations of n objects. A more descriptive term for these dissimilarities is "psychological distance" since these observations are generally obtained by relying upon human perception of the differences, or "distances," between all possible pairs of the n stimuli. These "psychological distance" measurements, or dissimilarity observations, are designated by the term $\delta_{ij}$, which represents the dissimilarity between stimuli i and j. The number of $\delta_{ij}$'s required is n(n-1)/2 since all possible distinct pairs are to be compared. Henceforth, the letter m will be used to represent the quantity n(n-1)/2.

The m dissimilarity measures are, in fact, ordinal measures and imply only rank order information. However, rank order is all that is desired. Once it is known that stimulus A is closer to stimulus C than to B and B is closer to A than to C, it is possible to place the points A, B, and C in a configuration in two-dimensional space such that the Euclidean distances between them correspond in rank order precisely to the rank order of the "psychological distances."

Thus, the respondents in an experiment yield judgments, or "psychological distances," of stimuli which can be ordered as follows:

$$\delta_{i_1 j_1} < \delta_{i_2 j_2} < \ldots < \delta_{i_m j_m}$$

The experimenter then desires to obtain a multidimensional mapping of n points whose interpoint distances, $d_{ij}$, come as close as possible to satisfying

$$d_{i_1 j_1} \leq d_{i_2 j_2} \leq \cdots d_{i_m j_m}$$

It is always possible to place n points in an (n-1)-dimensional space such that rank order between the points is preserved. However, quite often one desires to find a smaller dimensional space to describe the data. For instance, if there were twenty points, nineteen dimensions would be required. However, if one could find a configuration in three dimensions that would come very close to preserving the rank order relationships, such a reduction in dimensions would be extremely useful. This idea corresponds somewhat to the concept of parsimony in factor analysis.

2. Stress as a Measure of Monotonicity

In order to determine how close a configuration of points is to having a perfect monotone relationship with the $\delta_{ij}$'s, Kruskal introduces a measure called stress. Stress is represented as

$$\text{Stress} = S = \sqrt{\frac{\sum_{i<j} (d_{ij} - \hat{d}_{ij})^2}{\sum_{i<j} d_{ij}^2}}$$

where $d_{ij}$ is the Euclidean distance between points i and j and the $\hat{d}_{ij}$'s are a sequence of numbers having the same rank order as the $\delta_{ij}$'s but are chosen as closely as possible to the $d_{ij}$'s, the actual Euclidean distances in the configuration. For an example of the computation of stress, including the $\hat{d}_{ij}$'s, see Appendix A.

It is clear that the stress is zero if the term $d_{ij} - \hat{d}_{ij}$ is zero for all i and j. This, of course , means that there is no difference between the actual Euclidean distances and a sequence of numbers having the same rank order as the "psychological distances" between the n stimuli. Hence, given the desire to achieve a monotone relationship between the $d_{ij}$'s which is like the monotone relationship between the $\delta_{ij}$'s it is obvious that the objective is to obtain a configuration of points $(x_1, \ldots, x_i, \ldots, x_n)$ that will yield a stress as close to zero as possible.

Therefore, Kruskal has, in effect, formulated a non-linear program for multidimensional scaling of the form

$$\underset{x,\hat{d}}{\text{Minimize}} \qquad \text{Stress} = \sqrt{\frac{\sum_{\substack{i=1 \\ i<j}}^{n-1} \sum_{j=2}^{n} (d_{ij} - \hat{d}_{ij})^2}{\sum_{\substack{i=1 \\ i<j}}^{n-1} \sum_{j=2}^{n} d_{ij}^2}}$$

$$\text{Subject to} \qquad \hat{d}_{i_1 j_1} \leq \hat{d}_{i_2 j_2} \leq \cdots \leq \hat{d}_{i_m j_m}$$

$$\text{Whenever} \qquad \delta_{i_1 j_1} \leq \delta_{i_2 j_2} \leq \cdots \leq \delta_{i_m j_m}$$

where $d_{ij}$ is the Euclidean distance between point $x_i$ and point $x_j$. To perform this minimization in his program, Kruskal uses a modified gradient technique, which he discusses in some detail in Ref. 23.

Based upon his own experience with stress as a measure of goodness of fit of a configuration of points, Kruskal has made an empirical assignment of word descriptions

for selected values of stress to indicate the degree of acceptability of the solution. He states the relationships as follows [Ref. 22]:

| Stress | Goodness of fit |
|---|---|
| .200 | Poor |
| .100 | Fair |
| .050 | Good |
| .025 | Excellent |
| .000 | Perfect |

It should be noted that Kruskal multiplies these values by 100 and lists stress as a percentage; e.g., 20% instead of .200. There is no reason to do this, since the result of the computation would be .20 and not 20. Additionally, the KYST program does not output the answer as a percentage. Hence, any mention of stress herein will be in decimal form and not in percentages.

An important omission in Kruskal's discussion of stress is his failure to treat the problem of an increase in stress due solely to an increase in the number of points being scaled. For instance, twenty-five points scaled in three dimensions is likely to have a higher stress than fifteen points in three dimensions simply because the non-linear program for minimization of stress has more constraints. Hence, Kruskal's criteria for measuring acceptability of stress do not take into account the difficulty of achieving a low stress with a greater number of points. Also, for a given number of points, the stress is likely to decrease (actually it will be non-increasing) as the number of dimensions increases.

There have been several studies of the significance of stress as a measure of goodness of fit. Herbert Stenson and Ronald Knoll [Ref. 38] attempted to find a crude probability distribution for stress values for random data, i.e. randomly generated $\delta_{ij}$'s. They looked at stress for ten through 60 points in increments of ten, and offered a rather conservative rule for rejecting a solution as being generated from random data. David Klahr [Ref. 18] performed a much more thorough analysis for six, seven, eight, ten, twelve, and sixteen points. He was able to make more definitive statements about the probability distribution for these points. For example, from Klahr's Table 2, one can observe that for 16 points, there is a probability of .05 of obtaining a stress of .170 or less in three dimensions by using random data. These two studies will be used later as a benchmark from which to judge the validity of solutions obtained by multidimensional scaling.

## B. OUTLINE OF THE BASIC SOLUTION PROCEDURE IN THE KRUSKAL ALGORITHM

The solution procedure for the nonlinear program is a modified gradient technique. Once the dissimilarities between objects have been obtained, they are then ordered in a monotone increasing fashion. If similarities are used, the ordering is monotone decreasing. Then, an initial configuration of points is constructed. The stress and the gradient of stress are calculated for the initial configuration. An appropriate step-size is computed and movement is made along

the gradient for the amount of that step-size. Stress and gradient are calculated for the new configuration and compared to the desired stopping criteria. This procedure is continued until the stopping criteria, as specified by the user of the program, are satisfied. For the details of the algorithm, see Ref. 7.

## C. PROBLEM OF LOCAL MINIMA

As with any minimization problem involving a non-unimodal objective function, it is possible to arrive at a local minimum rather than a global one. Kruskal has recognized the possibility of such an adverse circumstance. However, he attempts to minimize the impact of the problem by stating that (1) several solutions can be obtained using different initial configurations and compared for the lowest stress; (2) a configuration produced by a local minimum is probably not far wrong if the configuration lends itself to an intelligent interpretation; (3) the stress must be low to make the solution of interest anyway; and (4) it is possible to make a very close examination and comparison of the data and the solution for inconsistencies. While these statements are true, the problem is one of some consequence. It is quite possible that a local minimum will prevent the iterative procedure from arriving at a solution which is either interpretable, has a low stress, or both, even though such a solution may exist. Unfortunately, there is no guaranteed way to guard against such an unpalatable eventuality. Some

studies of multidimensional scaling techniques have been conducted to determine among other things, their susceptability to this phenomenon.

Ian Spence [Ref. 37] and Harold Spaeth and Scott Guthery [Ref. 36] examined several multidimensional scaling algorithms and found that, indeed, they were subject to local minima. Spence examined TORSCA-9, SSA-I, and MDSCAL using Monte Carlo simulation. Spaeth and Guthery studied SSA-I and MDSCAL using geometrical shapes as input.

To counter the local minimum problem, as well as to incorporate other features, Kruskal combined parts of his MDSCAL program with parts of TORSCA-9 by Torgerson and Young to produce KYST, a considerably improved program for which apparently no comparative studies have been published to date. However, KYST should perform better than MDSCAL since it embodies some of the best elements of MDSCAL and TORSCA-9.

## D. DETERMINATION OF NUMBER OF DIMFNSIONS

Before any results can be obtained, the experimenter must be able to determine how many dimensions to extract from the data. This is probably the most difficult part of the analysis. Kruskal offers three criteria for this task. First, the program should be run in several dimensions and a stress versus dimensionality plot should be made. If there is a distinct "elbow" in the curve connecting the values of stress at a given dimension, say three, this would indicate that four or more dimensions have only slightly

better stress. Hence, one could explain the data just as well by using three dimensions as he could by using more. Second, one must be able to interpret the dimensions he extracts. It is obvious that stress is non-increasing as the number of dimensions increases. However, if one can only interpret the results in two dimensions, it makes little sense to use three or more merely because the stress is slightly lower. Third, if the data is very accurate, one can supposedly use more dimensions [Ref. 22]. However, as Stenson and Knoll [Ref. 38] have noted, the exact relation of the accuracy of the data to the number of dimensions one can extract is unclear. Shepard [Ref. 34] has added a fourth criterion. He says that the solution should be readily visible to the human eye and hence, of two, or at most three, dimensions. This last recommendation is debatable since if more than three dimensions are required, one would think that they should be used. Shepard acknowledges this but strongly urges that the experimenter should stop at three dimensions if at all possible. His basic argument is that a large number of dimensions will present problems of presentation and may even confuse the issue rather than enlighten the experimenter.

# III. "AN AXIOMATIC MODEL OF VOTING BODIES"

As discussed previously, in order to use multidimensional scaling to identify dimensions of voting, one must have some measure of similarity-dissimilarity between votes. A measure called Relative Agreement, described in an article by Steven Brams and Michael O'Leary [Ref. 3], was used for this purpose. A discussion of the salient points in the article pertaining to Relative Agreement follows.

## A. FOUNDATIONS OF THE MODEL

Brams and O'Leary go to great lengths to explain that they attempted to construct a model, beginning with definitions and axioms, which would provide a rigorous development of indexes and measures to be used in the analysis of voting data. The index of interest for this thesis is related to agreement between votes. Hence, only selected portions of the model will be treated here.

### 1. Probability of Agreement of Two Randomly-Selected Members on a Given Roll Call

For this model, a member in a voting body is permitted three options. He may vote "yes," "no," or he may abstain from voting. With these options as a basis, after a roll call has occurred the probability that two randomly-selected members, r and s, agreed on the roll call can be computed. This probability is just the sum of the probabilities that the two members both voted "yes," both voted "no," or both abstained. The probability of two randomly selected members

having voted "yes" is simply the ratio of the possible number of ways two members could vote "yes" to the total possible numbers of pairs, or

$$P(Y_r, Y_s) = \frac{\binom{y}{2}}{\binom{t}{2}} = \frac{y!}{2!(y-2)!} \cdot \frac{2!(t-2)!}{t!}$$

$$= \frac{y(y-1)}{t(t-1)}$$

Similarly, the probability of two "no" votes is

$$P(N_r, N_s) = \frac{\binom{n}{2}}{\binom{t}{2}} = \frac{n(n-1)}{t(t-1)}$$

and the probability of two abstentions is

$$P(A_r, A_s) = \frac{\binom{a}{2}}{\binom{t}{2}} = \frac{a(a-1)}{t(t-1)}$$

The lower case letters y, n, a, and t indicate the number of "yes," "no," "abstain" and total votes, respectively, for a particular roll call. Therefore, the "Probability of Agreement" of two randomly-selected members on a given vote is

$$P(AG_{rs}) = \frac{y(y-1) + n(n-1) + a(a-1)}{t(t-1)}$$

It must be pointed out that the actual distribution of votes must be known, after the fact, to determine this probability. For example, if it is known that for a ten-man voting body, on a particular vote there were five affirmative votes, three negative votes, and two abstentions; i.e., $y = 5$, $n = 3$, $a = 2$, the probability of agreement for that vote is

$$P(AG_{rs}) = \frac{y(y-1) + n(n-1) + a(a-1)}{t(t-1)} = \frac{5(4) + 3(2) + 2(1)}{10(9)}$$

$$= \frac{14}{45} \doteq .311.$$

It should also be noted in passing that the probability of agreement changes with the size of the voting body. For a one-hundred member body split in a ratio of five to three to two as before, the probability of agreement would be

$$P(AG_{rs}) = \frac{50(49) + 30(29) + 20(19)}{100(99)}$$

$$= \frac{37}{99} \doteq .374$$

This change in $P(AG_{rs})$ occurs simply because, when the number of voting options remains constant, there are more ways for two members to agree in a one-hundred-member body than in a ten-member body, or alternatively, as Brams and O'Leary view it, there are fewer ways for two members to disagree. As a result of this rather unfortunate anomaly, P(AG) and Relative Agreement, a measure which is based on it, are valid measures of agreement only for voting bodies of the same size. This fact will become significant later in the analysis.

2. Axioms of the Model

Brams and O'Leary propose two axioms as the basis for the development of their model. The first axiom is stated as follows:

> Axiom 1. If $P(DG_{rs})$ is equal to the probability that two randomly-selected members r and s disagree on a roll call,
>
> $$P(AG_{rs}) + P(DG_{rs}) = 1$$

This axiom merely states that the events "agreement" and "disagreement" between two members on a given roll call are mutually exclusive and collectively exhaustive.

Axiom 2 has provoked some controversy in the literature. It appears as

> Axiom 2. The probability of agreement of two randomly-selected members on a roll call(s) is statistically independent of the probability of agreement on any other roll call(s). More formally, the number of agreements of two randomly-selected members on each roll call (0 or 1) are mutually independent random variables.

Aside from the fact that probabilities are not independent, events are independent as Mayer [Ref. 31] noted, the authors admit that this particular stipulation is unrealistic in view of the well-known propensity of politicians to bargain for votes. For instance, an affirmative vote on an issue affecting New York City may be traded for an affirmative vote on a farm bill affecting Iowa. Additional and perhaps more serious violations, as Brams and O'Leary recognize, occur when a voter comes from a fairly homogeneous political/ geographical region; e.g., a Southern Democrat, or whenever any other situation, such as strict party discipline, introduces a consistent bias into the voting behavior of members of that body. However, as Mayer has shown [Refs. 31 and 32] the independence assumption of Axiom 2 is not necessary for most of the desired indexes derived in this model if some adjustments in the computational formulas are made. Indeed, Brams and O'Leary point out [Ref. 4] that the assumption of independence is not needed to obtain the expression for Expected Agreement between two randomly selected members,

$E(AG_{rs})$, over a set of roll calls. In fact, they even go so far as to state that [Ref. 4]

> . . . All our indicators, with the exception of the variance level (VL) measure which does depend on the independence assumption, are unaffected when his [Mayer's] probabilities are substituted for ours.

This statement can be made because of the fact that mathematical expectation is a linear operator. The expected value of the sum of n random variables is equal to the sum of the expected values of the n variables [Ref. 33]. The preceeding statement is true whether or not the random variables are independent. Hence, the calculation of $E(AG_{rs})$, as the sum of the E(AG), or $P(AG_{rs})$, for all of the individual roll calls in which r and s vote, is a valid one. However, the authors mention one index in footnote 35 where a type of independence assumption is not only necessary but desirable for the index to be meaningful. This index is Relative Agreement between votes (rather than members) and will be discussed in the next section.

## B. RELATIVE AGREEMENT BETWEEN VOTES

Brams and O'Leary have defined their Relative Agreement indicator as follows:

$$RA_{ij} = \frac{AG_{ij} - E(AG_{ij})}{E(AG_{ij})}$$

where $RA_{ij}$ is the Relative Agreement between roll-call votes i and j, $AG_{ij}$ is the actual number of "agreements" between

votes i and j, and $E(AG_{ij})$ is the expected number of "agreements" between the two roll-calls.

The quotation marks around agreements in the previous paragraph are used to indicate the expanded definition of agreement implicit in this index. Two members, r and s, are said to have "agreed" on votes i and j if they voted the same way with respect to each other on each vote. Members vote the same way on two votes if they agree with each other or disagree with each other on both votes; i.e., take mutually consistent positions on the two votes. For example, if member r votes "yes" and member s votes "yes" on vote i, then they must both vote either "yes," "no," or "abstain" on vote j to "agree" for votes i and j. Also if member r votes "yes" and member s votes "no" on vote i, or vice versa, then the votes of members r and s must be different on vote j to "agree" on i and j. Through this broader definition of agreement, one can determine that two members view two votes as similar, in some sense, if they "agree" on the votes. By making all comparisons of pairs of voters for two roll calls, i and j, using the criteria discussed above, one can obtain $AG_{ij}$, the actual number of "agreements" between i and j.

The calculation of $E(AG_{ij})$ requires the computation of the total probability of "agreement" between i and j. This total probability of "agreement" is defined as the sum of the products of $P(AG_{rs})_i$ and $P(AG_{rs})_j$ and the product of $P(DG_{rs})_i$ and $P(DG_{rs})_j$. Thus,

$$P(AG_{ij})_{total} = P(AG_{rs})_i \; P(AG_{rs})_j + P(DG_{rs})_i \; P(DG_{rs})_j$$

The $E(AG_{ij})$ is simply the product of $P(AG_{ij})_{total}$ and the total possible number of pairs in the voting body or

$$E(AG_{ij}) = P(AG_{ij})_{total} \times N$$

where N represents the total number of distinct pairs. By multiplying the $P(AG_{rs})$'s and the $P(DG_{rs})$'s together, one is assuming that agreement between two randomly-selected members on vote i is independent of agreement between two randomly-selected members on vote j. The assumption of independence is desirable for this indicator since one is interested in determining whether or not two votes are similar or disimilar as viewed by the legislature as a whole. By utilizing $RA_{ij}$ as an index, one is able to obtain some measure of the departure from independence, in the aggregate, for the two votes. Looking back at $RA_{ij}$, it is clear that a negative value indicates that there are fewer "agreements" than expected under the assumption of independence; i.e., $AG_{ij}$ is less than $E(AG_{ij})$. This is an indication that the votes are, in some sense, dissimilar. In like fashion, a positive value indicates more agreements than expected and hence the votes are taken to be similar.

However, it must be observed that this measure is an ordinal one. A Relative Agreement of .700 does not mean that the two votes compared are twice as similar, on any kind of scale, as two votes which have a relative agreement of .350 even if one vote appears in both pairs. Such a situation would merely imply that the two votes with a .700 value are more similar than the two votes with a .350 value.

It must be remembered that there is a problem with the application of this index in practice. Relative Agreement comparisons are valid only for measuring agreement on votes for which the size of the voting body remains constant because $P(AG_{rs})$ changes with the size of the voting body. For this reason, the use of Relative Agreement will be limited to those cases where the number of members does not change. The problem, as it applies to this thesis, will be discussed further in a later section.

Thus, Relative Agreement provides an ordinal measure of the similarity between roll call votes, the type of measure which is needed to perform multidimensional scaling on different roll call votes. In terms of the earlier notation, Relative Agreement between votes i and j, $RA_{ij}$ will correspond to the dissimilarity measure, $\delta_{ij}$, discussed in the section on multidimensional scaling. In order to further explain this measure, an example of the calculation of $RA_{ij}$ is presented in the next section.

## C. EXAMPLE OF CALCULATION OF RELATIVE AGREEMENT BETWEEN VOTES

Consider a hypothetical five-man voting body which has cast the following votes on three roll calls:

| VOTES | MEMBERS | | | | | $P(AG_{rs})$ | $P(DG_{rs})$ |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| 1 | Y | N | Y | N | A | .2 | .8 |
| 2 | N | Y | Y | N | Y | .4 | .6 |
| 3 | Y | N | N | N | N | .6 | .4 |

For votes one and two, the total "probability of agreement" is

$$P(AG_{12})_{total} = P(AG_{rs})_1 \; P(AG_{rs})_2 + P(DG_{rs})_1 \; P(DG_{rs})_2$$

$$P(AG_{12})_{total} = (.2)(.4) + (.8)(.6) = .56$$

For votes one and three

$$P(AG_{13})_{total} = (.2)(.6) + (.8)(.4) = .44.$$

For votes two and three

$$P(AG_{23})_{total} = (.4)(.6) + (.6)(.4) = .48.$$

The total number of pairs is $\binom{5}{2}$ or ten. Therefore, the E(AG) values are

$$E(AG_{12}) = .56(10) = 5.6$$

$$E(AG_{13}) = .44(10) = 4.4$$

$$E(AG_{23}) = .40(10) = 4.8$$

The number of "agreements" between one and two is four, because members one and two, one and five, three and four, and four and five "agree" on votes one and two. Hence,

$$RA_{12} = \frac{AG_{12} - E(AG_{12})}{E(AG_{12})}$$

$$= \frac{4 - 5.6}{5.6} \doteq -.29$$

Similarly,

$$RA_{13} = \frac{AG_{13} - E(AG_{13})}{E(AG_{13})}$$

$$= \frac{4 - 4.4}{4.4} \doteq -.09$$

and

$$RA_{23} = \frac{AG_{23} - E(AG_{23})}{E(AG_{23})}$$

$$= \frac{6 - 4.8}{4.8} = .25$$

Thus if these three votes were rank ordered in pairs according to increasing similarity (Relative Agreement), the ordering would be

| | | | |
|---|---|---|---|
| Votes | 12 | 13 | 23 |
| $RA_{ij}$ | -.29 | -.09 | .25 |

The procedure discussed in this example was used to obtain measures of dissimilarity between all sets of votes analyzed herein.

## IV. DISCUSSION OF PROCEDURE USED IN THE ANALYSIS

The information on roll-call votes for this analysis was obtained from data compiled by Congressional Quarterly, Inc., a non-partisan Washington, D.C. firm which, among other things, records all roll-call votes of Congressmen and Senators. If any member fails to vote or go on the record for a particular roll call, Congressional Quarterly sends that member a questionnaire asking his position for that vote. As a result of this procedure, called the CQ poll, "voting participation" as defined by Congressional Quarterly is, in general, very high. For the years covered by this analysis, "voting participation" in the Senate as a whole for all roll calls was 95% in 1969 [Ref. 8, p. 1036], 91% in 1970 [Ref. 9, p. 1135], and 93% in 1971 [Ref. 10, p. 92].

To aid those studying the Congress, Survey Research Center at the University of Michigan maintains Congressional Quarterly roll-call data on magnetic tape. Voting information for the votes analyzed in this thesis was obtained from these magnetic tape records. In addition, for further background on votes, Congressional Quarterly Almanacs were consulted.

### A. COMPUTATION OF THE RELATIVE AGREEMENT INDEX

#### 1. The Problem of Different Numbers of Voters for Different Roll Calls

The first problem to arise in the computation of Relative Agreement was the necessity of having voting bodies

of the same size. As is well-known, not all Senators vote on every roll call. Thus, there may be 78 Senators voting on bill X and 93 Senators voting on bill Y. Using Relative Agreement for these two votes would not accurately measure the "agreement" between the two since the number of voters is different. As mentioned previously, probability of agreement changes with the size of the voting body and this biases the Relative Agreement index. However, since voting participation from Congressional Quarterly records is high for the Senate and one might reasonably view a failure to respond to a CQ poll as an abstention, the following procedure was used. All votes recorded as "yes," "paired for," and "announced for or CQ poll for" were considered "yes" votes for the purposes of this analysis. All votes recorded as "nay," "paired against," and "announced against or CQ poll against" were considered "no" votes. Votes listed by Congressional Quarterly as "not voting," "voted 'present'," and "did not announce" were considered abstentions. Thus, for a vote with 29 yeas, 61 nays, one paired for and one paired against, three announced for, two announced against, and three not voting, the values for computation of $P(AG_{rs})$ would be $y = 33$, $n = 64$, and $a = 3$.

2. <u>The Problem of One Voter Leaving the Legislature and Being Replaced by Another</u>

The Relative Agreement index requires that one be able to compare member r's response on vote number one to member s's response on the same vote and then compare their responses on all succeeding votes to obtain Relative Agreement

for vote number one with all other votes. Suppose, however, that member s is replaced by member u on vote number six. It is not possible to compare votes one through six with votes coming afterward unless one is prepared to assume that member u would have responded in exactly the same manner as member s for the first six votes had member u been in the body instead of member s. Such an assumption would be unjustified in many cases and in all cases one could never be sure of the validity of the assumption. Therefore, instead of attempting to make such an assumption, voters were simply dropped when they were either replaced or were replacements. During the 91st Congress, Senator Everett Dirksen of Illinois died and was replaced by a political appointee, Ralph Smith, until the election in 1970 in which he was defeated by Adlai Stevenson, III. Stevenson took the seat for the remainder of the session. It would be unreasonable to assume that these three men would have all voted exactly the same way on all roll calls. Hence, Senator Dirksen's seat was dropped from the analysis for 1969-1970 and only 99 Senators were included in the Relative Agreement computations. For 1971, Senator Winston Prouty of Vermont died and was replaced by Robert Stafford so Senator Prouty's seat was dropped. Senator Richard Russell of Georgia died in early 1971, but his replacement, David Gambrell, arrived soon enough to vote on the first defense vote so the Russell seat was retained. However, Senator Karl Mundt of South Dakota was ill the majority of the 1971 session and his seat was also dropped since a failure to vote could not

reasonably be considered an abstention in this case. Therefore, there were only 98 Senators considered in the 1971 session.

B. SELECTION OF VOTES

The method for selection of votes was an iterative process. Votes initially selected for inclusion in the study were all those from the session which were defense-oriented. Two lists were prepared for each period (1969-1970 and 1971). A "short" list of 42 votes for 1969-1970 and another "short" list of 48 votes was compiled for 1971. A "long" list of 60 votes was then compiled for both periods. KYST is limited to 60 points and this capacity limitation precluded the use of more votes.

The original list for 1969-1970 contained over 100 votes. Therefore, a "first cut" approach to culling some votes was needed. This problem is common to almost all voting studies. One must have some criterion for reducing the number of votes under consideration. The choice of this criterion is often purely arbitrary. In this case, the criterion mentioned by David Koehler in Ref. 19 was used to initially reduce the list of votes. After an examination of eleven sessions of Congress, Koehler came to the conclusion that any roll call in which the opposition mustered at least 15% of the vote was one in which a significant degree of contesting was found. It should be noted that there are other criteria such as amount of voting participation and an index measuring both degree of contesting and voting participation called Riker's

significance coefficient which may be found in Chapter Five of Ref. 2. However, any of the measures are, to some degree, arbitrary.

An additional reason for the choice of Koehler's approach is the fairly large number of defense appropriations type bills where the vote is unanimous or very nearly so. Agreement on these votes does not generally mean the same thing as agreement on votes that are contested. A Senator may have reservations about certain aspects of an appropriations bill, for example, but will vote for it because there is no way for him to use an item veto on those parts he dislikes. Hence, the agreement on this type of bill is artificially inflated, and such votes would tend to bias any results if they were included in the analysis. As a result of these considerations, it was decided to use Koehler's method of vote selection for this study.

After applying the 15% criterion to the initial list of votes for 1969-1970, 43 votes were dropped. There were 14 votes in 1971 which had less than 15% opposition.

Reduction of the list of votes by the Koehler criterion still left too many votes for both years. At this point, votes were subjectively selected by the author to obtain what was thought to be a manageable number. In the case of the 1969-1970 data, this manageable number was 42 votes for the "short" list and 60 votes for the "long" list.

The subjectivity in vote selection alluded to earlier simply means that the author eliminated those votes which did

not appear to be primarily defense-oriented in nature, even though there were implications for defense in the bill. For example, a vote on the establishment of a standing committee on Veterans' Affairs, while related to defense, was not deemed to be primarily a defense issue and was dropped from the list. Also, a bill assuring the validity of laws exempting women from compulsory military service was not considered primarily a defense issue. This same subjective criterion was used for eliminating other votes to reach the numbers in the "short" list and the "long" list. The upper limit on the number of votes for the "long" list was, of course, 60 as previously discussed. The number on the "short" list was not fixed but it was simply the case that 42 votes appeared to have strong defense implications.

A FORTRAN computer program was written to calculate Relative Agreement and these computations were made for both 42 votes and 60 votes. However, there were two problems with this technique. First, votes were not selected either systematically or randomly, but subjectively. Second, the KYST solutions obtained were so cluttered with a large number of points that interpretation of dimensions was virtually impossible.

In an attempt to eliminate the second problem, sixteen votes for 1969, eighteen votes for 1970, and a combined list of twenty-one votes for 1969 and 1970 were chosen by the subjective method described previously with even more stringent criteria being applied for a primarily defense-oriented vote.

Multidimensional scaling solutions were obtained via KYST. However, the first problem of subjective bias in vote selection was still present. To counter this, a final selection of votes was conducted on a systematic basis. The lists of defense-oriented votes for 1969-1970 and 1971 were re-compiled after dropping all votes with less than 15% opposition. Then every third vote was selected. The final two lists for 1969-1970 and 1971 both contained 20 votes, and these lists were the ones used to obtain and report the results from this thesis. These two sets of votes are recorded in Appendix B.

## C. USE OF REGRESSION ANALYSIS

### 1. Interpretation of Dimensions and Selection of Number of Dimensions

Even after reducing the number of votes to the 16 to 20 range, there were still problems in interpreting the solution and selecting the appropriate number of dimensions. The matter of interpretation appears to be a universal problem in the application of multidimensional scaling [Refs. 16 and 22]. To circumvent this problem, regression programs were run for both sets of 20 votes with the dependent variable being pro-defense proportion of the vote and the independent variables being the coordinates obtained from the KYST solution. The pro-defense proportion of the vote on a given roll call was defined to be that proportion which supported the President's position as stated by Congressional Quarterly, or which supported the position of the majority of Republicans plus Southern Democrats; i.e., the

Conservative Coalition. Such a criterion was considered to be much better than attempting to classify votes subjectively as pro-defense merely by looking at the subject and wording of the bill when the President's position was unknown.

Such a pragmatic approach to the problem of interpretation would seem to have great value in those situations where the analyst has some quantifiable dependent variable which he desires to explain. As will be discussed later, the solution to the regression program in three dimensions for both 1969-1970 and 1971 showed that one variable was not significant and could be dropped. This greatly reduced the difficulties of interpretation since efforts could be devoted solely to two dimensions. A similar approach using multiple linear regression was used in Ref. 16.

2. Usefulness of Regression Results

Another equally important reason for using regression analysis was a desire to ascertain the relationship between pro-defense proportion of the vote and the dimensions of the solution. In addition, significant results from the regression analysis would provide convincing evidence that the data had not been manipulated in some way to produce desired results.

In addition, if a reasonable and significant relationship between the dependent variable and the independent variables could be obtained, inferences might be drawn about how best to proceed in presenting arguments for a given program. The sign of regression coefficients should give an

indication of the direction of influence of a particular dimension. For instance, a positive sign would indicate that an emphasis on the defense program's characteristics which were the same as those associated with the positive portion of that dimension should have a tendency to increase the pro-defense proportion of the vote. Thus, the regression analysis should assist in providing a basis for determining which strategies to employ when presenting the program to the Senate for approval.

## D. VALIDATION OF THE MODEL FOR 1969-1970

Two techniques were used to validate the 1969-1970 regression model with the 1971 data. First, a Chow test [Ref. 39, p. 147] for the difference between two regressions was run for the regression equations obtained for 1969-1970 and 1971. Second, the 1969-1970 regression model was used to predict the 1971 pro-defense proportion of the vote for all 20 votes for 1971 when using the coordinates from the 1971 KYST solution. Then a correlation between the actual and predicted values of pro-defense proportion of the vote was calculated.

## V. RESULTS AND CONCLUSIONS

The scaling solutions for the twenty points in both years were obtained using three different initial configurations in an attempt to avoid the problem of local minima. For each set of votes, one solution was obtained using the initial configuration that Kruskal took from the TORSCA-9 program and two others were obtained using random initial configurations. The resulting stress values are summarized below:

STRESS

| 1969-1970 | | | | 1971 | | | |
|---|---|---|---|---|---|---|---|
| | CONFIGURATION | | | | CONFIGURATION | | |
| Dim. | TORSCA-9 | Random | Random | Dim. | TORSCA-9 | Random | Random |
| 3 | .1131 | .1121 | .1140 | 3 | .1134 | .1203 | .1134 |
| 2 | .1721 | .1770 | .1736 | 2 | .1878 | .1796 | .1876 |

The solutions having the lowest stress were selected. [In general, the solutions for the same year and dimensions were very nearly the same. Differences in stress in the third decimal place do not seem to make an appreciable difference in the solution configuration.] For 1969-1970, the three-dimensional solution was the one having a stress of .1121 and the two-dimensional solution was the one having a stress of .1721. For 1971, the three-dimensional solution was the TORSCA-9 solution having a stress of .1134 and the two-dimensional solution was the one having a stress of .1796.

Before attempting to interpret the results, the criteria of Stenson and Knoll and Klahr were checked to test whether or not it was likely that the solutions were generated from random data.

Stenson and Knoll [Ref. 38] computed average stress values for similarities generated by random data for ten points through 60 points in one through ten dimensions. They then presented a conservative rule for accepting or rejecting the hypothesis that similarity data is random. The rule constructs something like an upper confidence interval for stress values of random data. The length of the interval is determined by the sample range of the stresses for each set of dimensions and points. If the value of stress obtained by an experimenter is closer to the average stress value for random data than twice the width of the sample range, the hypothesis of randomness cannot be rejected according to Stenson and Knoll. For both two and three dimensions, the width of the sample range was .02. The average stress was .21 for three dimensions and .32 for twenty points in two dimensions. Thus, one would reject the hypothesis of randomness in the similarity data for any stress value less than .17 (.21 - 2(.02)) in three dimensions and any value less than .28 (.32 - 2(.02)) in two dimensions.

Klahr [Ref. 18, p. 328] states that there is a probability of .05 of obtaining a stress less than .170 for 16 points in three dimensions and a probability of .05 of obtaining a stress less than .257 in two dimensions when scaling purely

random data. He did not perform tests for 20 points. However, at the .05 level, stress values always increased for the same number of dimensions when the number of points was increased. Hence, it would seem logical to extrapolate to values higher than .170 and .257 for twenty points.

Comparing the stress values from the two sets of votes to the criteria for random data, it is clear that the hypothesis that the similarity measures were generated from random data should be rejected. For the two-dimensional solution, the stress for 1969-1970 was .1721 and the stress for 1971 was .1796, both of which are less than .28 and .257, the Stenson and Knoll criterion and the Klahr criterion respectively. Therefore, the conclusion is that there is some underlying structure in the Relative Agreement measurements calculated for the Senate in the 1969-1970 and 1971 sessions.

## A. REGRESSION RESULTS AND INTERPRETATION OF DIMENSIONS

The three dimensions derived from the KYST solution for 1969-1970 and 1971 were used to obtain regression equations in terms of these variables to determine if all three contributed significantly to the explanation of the dependent variable, pro-defense proportion of the vote. The following statistics were obtained:

| 1969-1970 | | | 1971 | | |
|---|---|---|---|---|---|
| Variable | Regression Coefficient | T-Value | Variable | Regression Coefficient | T-Value |
| 1 | 0.08653 | 2.296 | 1 | 0.20830 | 16.932 |
| 2 | 0.11268 | 2.631 | 2 | -0.03484 | -2.635 |
| 3 | 0.01264 | 0.233 | 3 | 0.01548 | 1.065 |

The critical value of the t-statistic for 16 degrees of freedom is 2.120 at the .05 level of significance.

Thus, at this point, the three-dimensional solution was dropped since the third dimension did not appear to be significant. The two-dimensional solution was then used to obtain regression equations with the following results:

| 1969-1970 | | | 1971 | | |
|---|---|---|---|---|---|
| Variable | Regression Coefficient | T-Value | Variable | Regression Coefficient | T-Value |
| 1 | -0.08440 | -2.665 | 1 | -0.11627 | -9.286 |
| 2 | 0.10290 | 2.960 | 2 | 0.14322 | 10.746 |

Clearly both variables are significant for both regressions since the critical t-value is now 2.110 for 17 degrees of freedom at the .05 level.

Therefore, allowing Y to represent pro-defense proportion of the vote, the regression equations for the two sets of votes were

(1) $Y = .60294 - 0.08440X_1 + 0.10290X_2$ (1969-1970)

(2) $Y = .59009 - 0.11627X_1 + 0.14322X_2$ (1971)

The coefficient of determination ($R^2$) for equation (1) was .4828. For equation (2), $R^2$ was .9223. The $R^2$ for 1971 is extremely high and indicates a good fit of the regression equation to the data. The $R^2$ for 1969-1970 is obviously not as good but considering the type of data being analyzed, it is not totally unacceptable. Reasons for the difference in $R^2$ will be discussed later.

1. Interpretation of Dimensions

The most difficult portion of the analysis then ensued. The two dimensions had to be interpreted before any conclusions could be drawn. Many different possible dimensions were considered. Among these were:

1) Liberal/conservative sponsor of the bill

2) Pro-defense/anti-defense

3) Military Industrial Complex

4) Substantive versus ideological issues

5) Pro-technology/anti-technology

6) Non-partisan/partisan

7) Foreign policy/domestic policy

For the liberal/conservative sponsor of the bill dimension, ratings of Senators by Americans for Democratic Action, a liberal non-profit organization, were used to see if a pattern developed when these ratings for each bill's sponsor were placed beside the votes in a two-dimensional representation of the results [Refs. 11, 12, and 13]. However, this procedure failed to indicate that this dimension was present. Consideration of other dimensions by comparing the subject and wording of each bill with its relative position produced the same results except for non-partisan/partisan and foreign policy/domestic policy which appeared to be the dimensions represented in the solution.

The non-partisan/partisan hypothesis was tested by using a measure called Index of Party Likeness (IPL) found in Chapter Three of Ref. 2. IPL is defined as follows:

$$IPL = 100 - |\%YES_D - \%YES_R|.$$

$\%YES_D$ and $\%YES_R$ represent the percentage of Democrats and Republicans voting in favor of the bill. Thus, IPL is a measure of how equally divided the two parties are. If 100% of both parties vote "yes" on a given bill, IPL is 100 and the vote is totally non-partisan. If 60% of both parties vote "yes" on a bill, the IPL is still 100 and again the vote is totally non-partisan. However, if 75% of the Democrats vote "yes" and 25% of the Republicans vote "yes," IPL is 100 - 50, or 50. If 100% of the Democrats vote "yes" and 100% of the Republicans vote "no," IPL is 100 - 100, or 0. "Yes" percentages were based on voting participation records in Congressional Quarterly Almanacs and not on recorded roll call responses since Relative Agreement measures were based on voting participation figures as well. Index of Party Likeness scores were then calculated for the 20 votes in 1969-1970 and 1971 and are shown in Figures 1 and 2 beside the votes for which they were calculated.

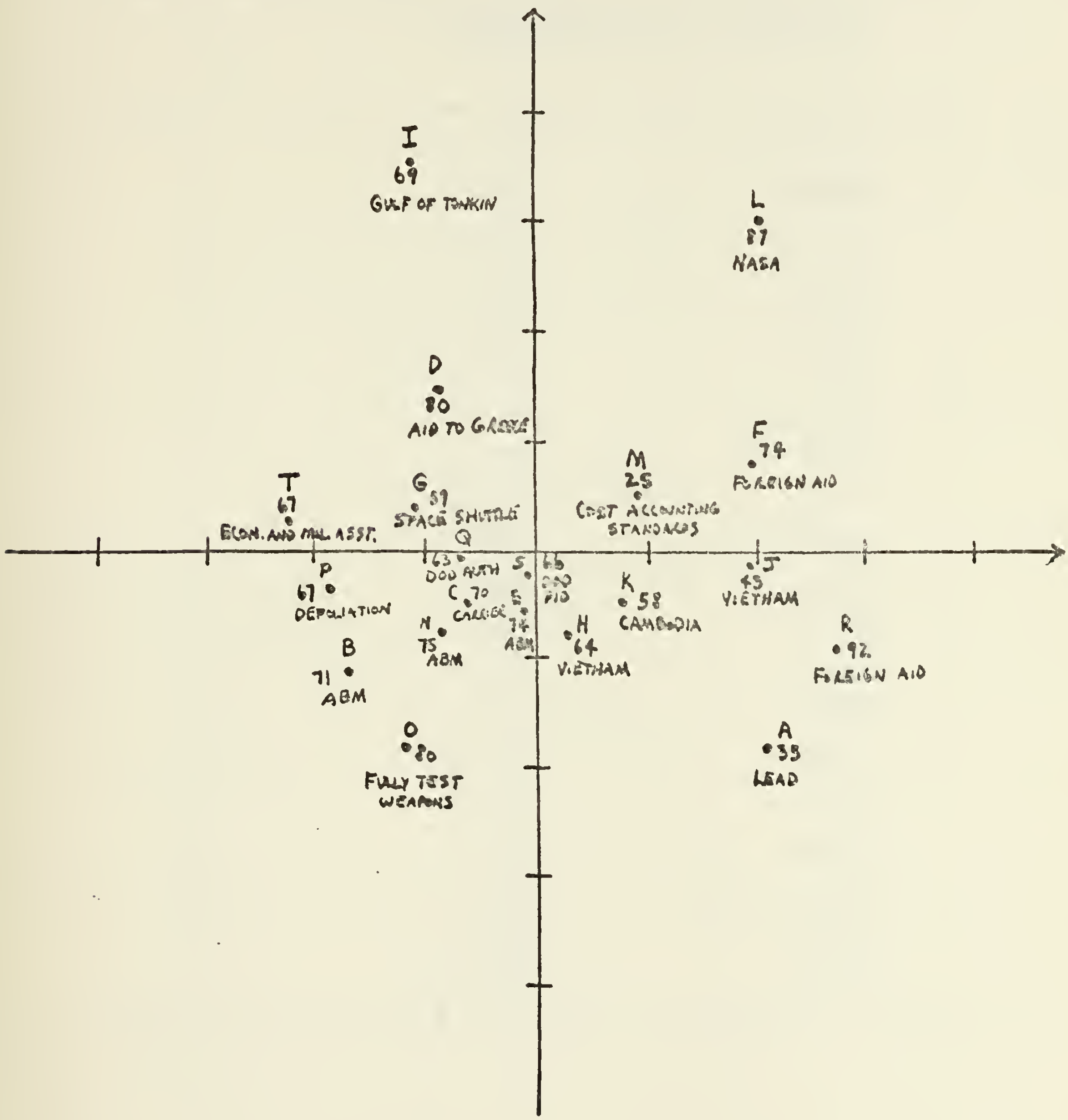
The IPL measure was used first for the 1971 data. It was suspected that the $X_2$ axis (dimension two from the KYST solution) might be non-partisan/partisan. After IPL figures were calculated for all 20 votes, a rank-order correlation computation was made based on the ranks of the IPL values for votes and the corresponding ranks of the $X_2$ coordinates for the same votes. Spearman's rho [Ref. 6, p. 156] was used for the calculation and found to be +.573

for the $X_2$ dimension. However, when vote D, a vote on military pay raises, was dropped from the calculations, rho jumped to +.760. Based on a t-test at the .05 level, the hypothesis that rho was zero was rejected in both cases. Thus, there appears to be a positive relationship between Index of Party Likeness and the $X_2$ dimension. For a visual comparison of IPL and the $X_2$ dimension, see Figure 2.

An examination of dimension $X_1$ for 1971 (dimension one from the KYST solution) revealed that practically all foreign policy votes appeared on the negative portion of the axis and practically all domestic policy votes appeared on the positive portion of the axis. Figure 2 illustrates this. Selected votes appear to be good indicators of the foreign policy/domestic policy dichotomy. Vote A, which had the most negative value on the $X_1$ dimension, was an amendment to reduce the number of United States military personnel in Europe from 300,000 to 150,000. Vote T had the next most negative value on that dimension and was an amendment to reduce the number of United States military personnel in Europe to 250,000. Other votes with negative values dealt with foreign military aid, the Vietnam War, and the Anti-Ballistic Missle system (ABM). The ABM system certainly had foreign policy implications such as the effect on the Strategic Arms Limitation Talks (SALT), detente with the USSR, and the arms race. Those votes which had stronger domestic aspects were located closer to the origin such as the vote on submission by the President of an alternate defense budget,

FIGURE 1

1969-1970 Vote Structure




Stress = .1721

TABLE 2

1969-1970 VOTES

| Vote | Coordinates for Dimension | |
| --- | --- | --- |
| | 1 | 2 |
| A | 1.047 | -0.928 |
| B | -0.893 | -0.509 |
| C | -0.321 | -0.257 |
| D | -0.469 | 0.730 |
| E | -0.082 | -0.292 |
| F | 0.984 | 0.396 |
| G | -0.558 | 0.181 |
| H | 0.166 | -0.401 |
| I | -0.596 | 1.774 |
| J | 0.993 | -0.091 |
| K | 0.392 | -0.286 |
| L | 1.012 | 1.509 |
| M | 0.441 | 0.250 |
| N | -0.442 | -0.441 |
| O | -0.598 | -0.927 |
| P | -0.924 | -0.207 |
| Q | -0.355 | -0.015 |
| R | 1.366 | -0.487 |
| S | -0.030 | -0.133 |
| T | -1.134 | 0.105 |

FIGURE 2

1971 Vote Structure


Stress = .1796

TABLE 3

1971 VOTES

| Vote | Coordinates for Dimension 1 | Coordinates for Dimension 2 |
|---|---|---|
| A | -1.022 | -0.122 |
| B | 0.756 | -1.392 |
| C | 0.590 | 0.109 |
| D | 1.329 | -0.536 |
| E | -0.096 | -0.080 |
| F | 0.944 | 0.763 |
| G | 0.228 | 0.476 |
| H | 0.023 | -0.684 |
| I | -0.706 | 0.968 |
| J | -0.141 | 0.105 |
| K | -0.200 | 0.446 |
| L | -0.275 | 0.225 |
| M | 1.842 | 0.828 |
| N | -0.540 | 0.382 |
| O | -0.582 | 0.721 |
| P | -0.714 | 0.224 |
| Q | -0.226 | -0.005 |
| R | -0.290 | -1.730 |
| S | -0.134 | -0.289 |
| T | -0.788 | -0.409 |

the Amchitka nuclear blast, and the F-14. The only vote that appears out of place on the negative portion of the axis is Vote I on the draft and military pay. However, any vote concerning the draft in 1971 contained anti-war implications and might be viewed, in that sense, as a foreign policy vote.

On the positive portion of the $X_1$ dimension, all votes are domestic votes with the exception of vote H on the termination of United States military operations in Indochina at the earliest practicable date. However, vote H is very close to the origin and does not appear to be seriously misplaced. Other votes with positive values deal with the supersonic transport (SST), military pay, and Reserve Officer Training Corps (ROTC) scholarships, all of which are domestic issues. A very interesting situation occurs when examining the most positive vote on the $X_1$ axis. Vote M has the highest positive value and concerns the Marine Corps' Harrier Aircraft which was being produced in Great Britain. This particular amendment would have eliminated funds to transfer production of the Harrier airframe from Great Britain to the United States. An examination of the 1971 Congressional Almanac [Ref. 10, pp. 318-319] reveals that the amendment was aimed at reducing the cost of the Harriers since a switch of production to the United States would have increased the total costs of production. The primary argument against the amendment was the prospect of increased employment in the St. Louis area since McDonnell-Douglas Aircraft Corporation was to receive the contract. It should be observed that

both Missouri Senators, Symington and Eagleton, opposed the measure. Thus, there is a strong indication that this vote was viewed in domestic terms.

As a result of this analysis, the two-dimensional solution for 1971 appears to clearly represent a non-partisan/ partisan axis and a foreign policy/domestic policy axis.

However, when considering the 1969-1970 two-dimensional solution, this result is not as clear. The rank-order correlation between the Index of Party Likeness and the corresponding $X_2$ coordinate was only -.01. When votes O and R, on fully testing weapons systems and foreign aid respectively, were dropped, the correlation rose to +.17. When two more of the original twenty votes (B and N which were both ABM votes) were dropped, the correlation went up to +.365. However, none of these passed a hypothesis test at the .05 level as being significantly different from zero. The argument that the $X_1$ dimension is foreign policy versus domestic policy is also not as clear. There are several votes out of place; however, the basic structure appears to be there. On the negative portion of the axis are votes on the Gulf of Tonkin resolution, aid to Greece, foreign economic and military assistance, ABM, and the use of defoliants in Vietnam. Votes on lowering the overall Department of Defense authorizations for 1971, a study of nuclear-powered aircraft carriers, and Department of Defense public information funds all were relatively close to the origin. But, one should observe that both Department of Defense appropriations and

aircraft carriers possess foreign policy implications. In addition, the bill on public information funds was only slightly negative. Thus, the only bill that seems somewhat out of place on the negative portion of the axis is the vote requiring full testing of weapons systems prior to their production. On the positive side of the axis, there are votes on funds for the National Aeronautics and Space Administration (NASA), cost accounting standards boards for defense contracts, and sale of lead from the national stockpile. However, there were several votes with foreign policy aspects in the positive direction, such as votes on Vietnam, Cambodia, and foreign aid. All in all, the argument that the dimensions for 1969-1970 and 1971 were the same seemed to be fairly weak at this point.

However, noticing the similarity between the regression equations and between the general location of points representing essentially the same type votes in both graphs, it appeared that there was some justification for the suspicion that the dimensions were the same. Two methods of validation were used to compare the two solutions. The first method was a Chow test for the difference between two regressions [Ref. 39, p. 147]. Results from the two earlier regressions and a single regression run with the combined samples of 1969-1970 and 1971 data were used to calculate the F-statistic for this test. The resulting F-value was .051. At the .05 level for three degrees of freedom in the numerator and 14 degrees of freedom in the denominator, the

critical F-value is 2.52. Thus, the null hypothesis for this test, that the two regressions are the same, could not be rejected.

The second method of validation was the use of the regression equation for 1969-1970 to predict 1971 pro-defense proportion of the vote using coordinates from the 1971 solution as the independent variables. The comparison of actual and predicted values appears in Appendix C. Calculations of the Pearson product moment correlation coefficient [Ref. 6, p. 152] between the actual and predicted values yielded a value of .9601. In effect, this result meant that the regression equation for 1969-1970 predicted the pro-defense vote for 1971 better than it did for 1969-1970, since the $R^2$ for 1969-1970 was only .4828 and $.9601^2$ is .9218. An equally interesting result was the finding that the predicted value accurately predicted whether the defense position would win or lose in 19 out of 20 votes, or 95% of the time.

2. Possible Reasons for Confounding in the 1969-1970 Data

The results of the Chow test and the correlations are compelling evidence that the two sets of dimensions are the same. There seem to be several possible reasons for the confounding taking place in the 1969-1970 solution.

First, the President took a position on only five out of the twenty votes in 1969-1970, but on ten votes out of twenty in 1971. This higher profile by the President in 1971 may have resulted in more political arm-twisting which could have produced a partisan reaction to Presidential methods.

Second, traditionally the Congress has attempted to go along with a new President as much as possible during his first Congress. However, the honeymoon is usually over after the first two years of his Presidency. This may account, in part, for the fact that the non-partisan/partisan dimension does not stand out as clearly as it does in 1971.

Third, there is good reason to believe that the 1969-1970 data represents a transition period during which the structure of the 1971 votes was emerging. As discussed previously, the strong opposition of Congress to defense measures really began in earnest in 1969. It may well be the case that Senatorial attitudes were developed during the 91st Congress into the very clear dimensions of the 1971 solution. Another consideration as well is the setback suffered by the Administration during the 1970 elections. Of 35 seats in the Senate, there were 25 Democratic incumbents and 10 Republican incumbents. In the November elections, Democrats won 22 seats and Republicans won 11, with one seat being won by a Conservative candidate and one being won by an independent. Although the Republicans made a net gain of two seats in the Senate, they lost more elections than they won in the Senate. Races for the House of Representatives and for Governors of states were definitely losses. Democrats made a net gain of 11 Governorships and 9 House seats [Ref. 9, pp. 1071-1073]. Congressional Quarterly commented [Ref. 9, p. 1073]

Despite the unprecedented off-year campaign efforts of President Nixon and Vice President Agnew, most observers felt the Republicans suffered a net loss in the Congressional and gubernatorial elections of Nov. 3, 1970.

Fourth, the perception of defense issues in terms of foreign policy aspects versus domestic policy aspects was crystallizing and may have been reflected in the 1970 off-year election. The domestic situation, i.e., inflation, had become so bad in 1971 that immense political pressures forced the President to impose wage and price controls and devalue the dollar in August of that year. These two actions further emphasized the conflict between foreign and domestic objectives.

Therefore, it appears that the 1969-1970 Congress represents a transition period from the rubber stamp era of the pre-1969 Senate to the clear-cut adversary structure of the 1971 Senate.

3. <u>Discussion of Regression Coefficients</u>

Before accepting a regression solution, one should examine the signs of the coefficients to determine if they are logical. Recall equations (1) and (2):

(1) $Y = .60294 - 0.08440X_1 + 0.10290X_2$ (1969-1970)

(2) $Y = .59009 - 0.11627X_1 + 0.14322X_2$ (1971)

The $X_1$ variable, which is foreign policy versus domestic policy, has a negative sign. This indicates that foreign policy, which is on the negative portion of the $X_1$ axis, has a positive effect on the pro-defense proportion of the vote; i.e., the more foreign policy implications a vote has the

higher its pro-defense vote is likely to be. Alternatively, the more domestic implications there are in a given vote, the less likely it is to have a high pro-defense vote. The first and most logical explanation for this is the natural tendency of the Congress to rally round the President on foreign policy issues. One would thus expect a positive relationship between the pro-defense vote and foreign policy since a pro-defense vote was defined largely as the President's position on a given bill. Second, the line of reasoning that says defense spending reduces unemployment and strengthens the economy has become increasingly discredited. Rather, the argument for reducing defense spending to reallocate that money to domestic programs has become more and more prevalent. Thus, any defense issue which relies largely on its implications for the economy is less likely to obtain a high pro-defense vote than in the past. Third, it would appear to be easy for a Senator to vote anti-defense on a largely domestic defense issue.

The sign of the coefficient for the $X_2$ variable is positive. This indicates that the more non-partisan a bill is the more likely it is to have a high pro-defense proportion of the vote. Conversely, the more partisan a bill, the less likely it is to have a high pro-defense vote. One would certainly expect this result since a negative relationship would indicate bi-partisan opposition to the President on defense issues, an unlikely state of affairs. In addition, the result is relatively obvious since the current President

is a member of the minority party. He has to have non-partisan support to get any bill passed, or defeated, The striking thing about this dimension is simply that it occurs at all. Traditionally, all defense issues have been non-partisan. However, here is a strong indication that this may no longer be the case.

## B. PROJECTED AREAS OF EMPHASIS IN FUTURE SUPPORT OF DEFENSE PROGRAMS BEFORE THE SENATE

After reviewing the signs of regression coefficients in the previous section, it appears that a partisan domestic issue has the least likelihood of achieving a high pro-defense vote. Hence, based on this analysis, proponents for the Department of Defense should stress the foreign policy implications of a defense bill or program and de-emphasize domestic implications. Every effort should be made to frame the argument in non-partisan terms. In addition, it might be better if more conciliatory efforts were made towards achieving bi-partisan support rather than portraying every vote, perhaps non-defense as well as defense, in terms of "us versus them." Indications are that a less combative approach, less critical of Congress, might yield better results than previous characterizations of Congress as wasteful and irresponsible. In short, a spirit of cooperation with Congress by the Administration might decrease partisan sentiments and achieve the desired results.

## C. INDICATIONS OF FURTHER RESEARCH

This effort has been an initial attempt to combine for the first time many different quantitative techniques into one study to examine attitudes in the Senate. While these results must be considered tentative, they are encouraging. The approach of this paper points to fruitful areas for further research.

### 1. Further Validation of 1969-1970 and 1971 Results

More work could be concentrated on the three years examined in this thesis, which appear to be pivotal with regard to future relations with the Senate. A possible approach would be a further attempt to validate these results by choosing votes to be scaled by both random as well as various systematic selection schemes. Further work might also be done with regard to enlarging the number of votes under consideration, even though that proved to be extremely difficult during this study. It would be very interesting to determine if the same results are obtained when different votes are used and larger numbers of votes are used. The methodology for these tests might well be a Chow test for the difference between two regressions based on votes from the same year or the same Congress.

### 2. Examination of Later Years

Further research should be conducted on later years to determine if the structure of voting in the Senate is emerging as has been hypothesized. Data for 1972 is currently available and comparisons between the 91st Congress and both sessions of the 92d Congress might further illuminate the

situation. Comparisons between 1971 and 1972 would also be interesting to see if shifts occurred during the 92d Congress. Of course, research on the 93d Congress can begin as soon as data is compiled after the end of this session. It would also be of interest to determine if the 1972 elections produced any discernible effect on the Senate's defense stance.

# VI. SUMMARY

The subject of roll-call analysis was introduced in Section I. A brief review of the literature showed that a study of roll call votes in the Senate on defense issues could be used to gain insight into the manner in which such issues are perceived by members of the Senate.

Section II discussed multidimensional scaling in some detail. J. B. Kruskal's technique was explained and some of the problems such as local minima and interpretation of dimensions were examined.

The Brams and O'Leary "Axiomatic Model of Voting Bodies" was covered in Section III with emphasis on the index called Relative Agreement between votes. Relative Agreement was the measure used in this thesis to obtain similarity observations for input to KYST, a computer program using Kruskal's multidimensional scaling technique.

Section IV contained a discussion of the procedure used to conduct the analysis of Senate voting. The problems with the use of the Relative Agreement index when applied to actual roll-call data were discussed. The method of vote selection for this analysis was described in detail and a pragmatic approach to the problem of interpretation of multidimensional scaling solutions was presented. This practical approach to interpretation involved the use of regression analysis as an aid to interpreting the solution.

[illegible]

In addition, the usefulness of regression analysis for this situation was discussed, along with the techniques used to validate the 1969-1970 model of pro-defense voting in the Senate.

Section V presented results of the analysis and conclusions to be drawn from these results. The multidimensional scaling solutions for twenty votes in both 1969-1970 and 1971 resulted in a two-dimensional interpretation of Senate perception of defense votes. The two dimensions were non-partisan/ partisan and foreign policy versus domestic policy aspects of defense issues. The regression model for 1969-1970 data was validated with votes from 1971 by means of a Chow test for the difference between two regressions and by comparing the actual values of pro-defense proportion of the vote for 1971 with the predicted values by using the Pearson product moment correlation coefficient. Based on the results for the time period under consideration, it would appear that partisan domestic issues have the least likelihood of obtaining a high pro-defense vote, while non-partisan foreign policy issues are most likely to obtain a high pro-defense proportion of the vote. Hence, for the Senate sessions examined, it would seem that arguments for defense programs emphasizing non-partisan foreign policy aspects of such programs would be most likely to succeed, while arguments appealing to partisan domestic aspects are most likely to fail.

## APPENDIX A

## THE D-HAT ALGORITHM

This appendix presents an example of the computation of stress for four points in two dimensions. The basic elements of the example are drawn from pages 80 to 82 in Ref. 29.

The "true" configuration of points is given in Figure 3 and will be used to show how the stress would be computed on the first iteration of the computer program. The axes are labelled X and Y merely for identification and have no physical or other significance.

From this "true" configuration, the actual distance between the points will be used to obtain the dissimilarities between items (points) A, B, C, and D. Thus the six pairs of dissimilarities are

$$AB = \sqrt{1^2 + 0^2} = 1$$

$$CD = \sqrt{1^2 + 1^2} = \sqrt{2}$$

$$BC = \sqrt{0^2 + 4^2} = 4$$

$$AC = \sqrt{1^2 + 4^2} = \sqrt{17}$$

$$BD = \sqrt{1^2 + 5^2} = \sqrt{26}$$

$$AD = \sqrt{2^2 + 5^2} = \sqrt{29}$$

Forming a monotone increasing ordering of dissimilarities yields

$$AB < CD < BC < AC < BD < AD$$

Figure 4 indicates the initial configuration of the four points. Again, the axes are labelled for identification only.

To determine the distances between points from the initial configuration, the distance function

$$d_{ij} = \left[ \sum_{\ell=1}^{t} |x_{i\ell} - x_{j\ell}|^r \right]^{1/r}$$

must be used. The number of dimensions, t, equals two and Euclidean distance is chosen so r also equals two. The computation for the distance from A to B is as follows:

$$d_{AB} = [|1-0|^2 + |0-1|^2]^{\frac{1}{2}} = \sqrt{2} \doteq 1.414$$

Similarly, the remaining distances are

$$d_{AC} = 1.0$$

$$d_{AD} = \sqrt{5} \doteq 2.24$$

$$d_{BC} = \sqrt{5} \doteq 2.24$$

$$d_{BD} = 1.0$$

$$d_{CD} = \sqrt{8} \doteq 2.83$$

Comparing the computed distances to the dissimilarity ordering to check the monotonicity requirement yields

| AB | CD | BC | AC | BD | AD |
|---|---|---|---|---|---|
| 1.41 | 2.83 | 2.24 | 1.00 | 1.00 | 2.24 |

Obviously, the ordering is not monotonically increasing as required. However, the stress must be computed to determine

Figure 3

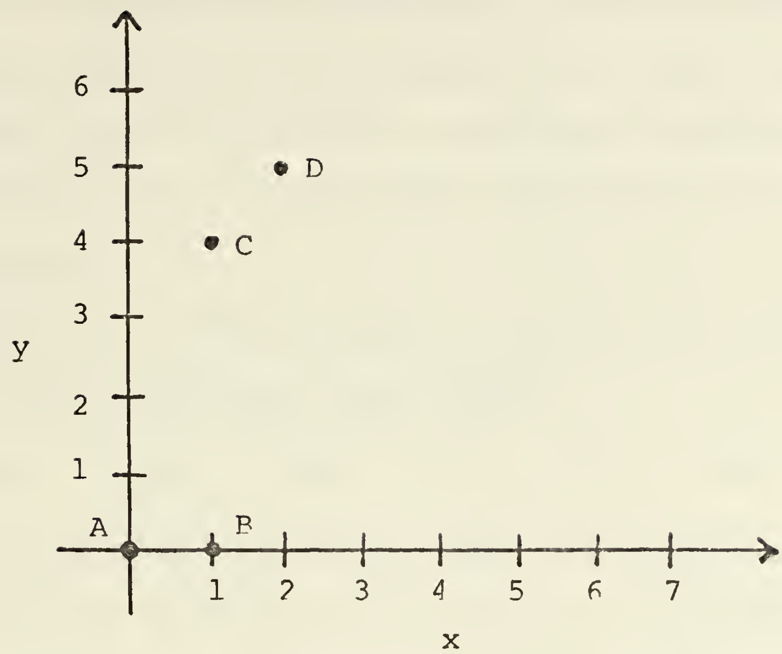
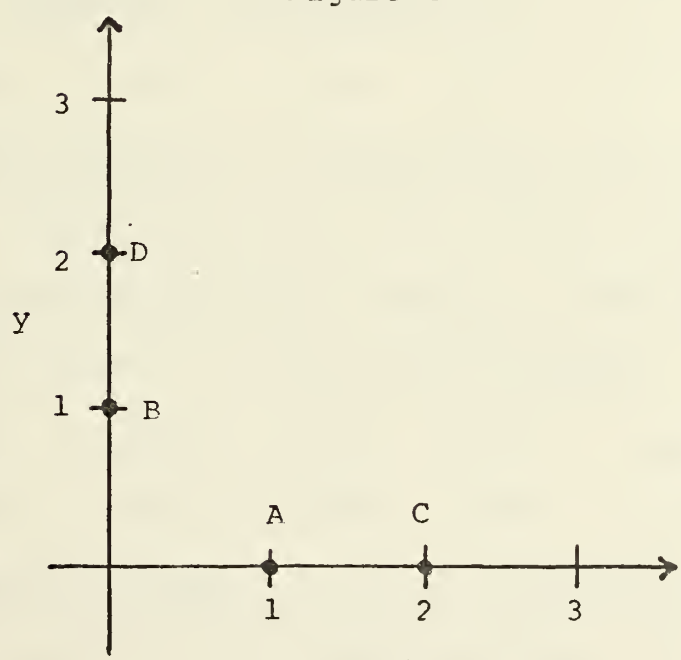



Figure 4



how close the configuration is to monotonicity. But before stress can be calculated, the $\hat{d}_{ij}$'s, a set of numbers satisfying the rank order constraints, must be computed. A detailed description of this computation occurs in Ref. 23 but the basic idea is to obtain a monotone ordering of numbers derived from the distances calculated from the trial configuration.

Beginning with the $d_{ij}$'s just computed and ordered as required by the constraint, one obtains

1.41    2.83    2.24    1.0    1.0    2.24

The first two numbers, 1.41 and 2.83, are monotone increasing but the next two, 2.83 and 2.24, are not. To produce a monotone ordering up to that point, 2.83 and 2.24 are averaged to yield 2.535. The first three numbers are now monotone. Presently, the ordering is

1.41    2.535    2.535    1.0    1.0    2.24

The averaging procedure is followed until the ordering is monotone. The following two lines indicate successive steps to reach a solution for the $\hat{d}_{ij}$'s. The last line is the solution since it is monotone increasing.

1.41    2.023    2.023    2.023    1.00    2.24

1.41    1.768    1.768    1.768    1.768    2.24

Before computing stress, it will be instructive to look at a plot of dissimilarities versus distances. The vertical axis on the graph represents dissimilarities and hence is an ordinal scale. The horizontal axis represents distance

($d_{ij}$ and $\hat{d}_{ij}$) and is an interval scale. A small x represents the distance, $d_{ij}$, obtained from the trial configuration; while a small o represents the $\hat{d}_{ij}$ calculated for the two points i and j except where $d_{ij} = \hat{d}_{ij}$. For this case, a small x is used to indicate both values. The distances along the dashed lines indicate the departure from monotonicity for each $d_{ij}$ and represent the terms $(d_{ij} - \hat{d}_{ij})$ which are squared in the numerator of the stress formula.

For this example, stress is calculated as follows:

$$\text{Stress} = S = \sqrt{\frac{\sum_{i<j} (d_{ij}-\hat{d}_{ij})^2}{\sum_{i<j} d_{ij}^2}}$$

$$= \left[\frac{(2.83-1.768)^2+(2.24-1.768)^2+(1.0-1.768)^2+(1.0-1.768)^2}{(1.41)^2+(2.83)^2+(2.24)^2+(1.0)^2+(2.24)^2+(1.0)^2}\right]^{\frac{1}{2}}$$

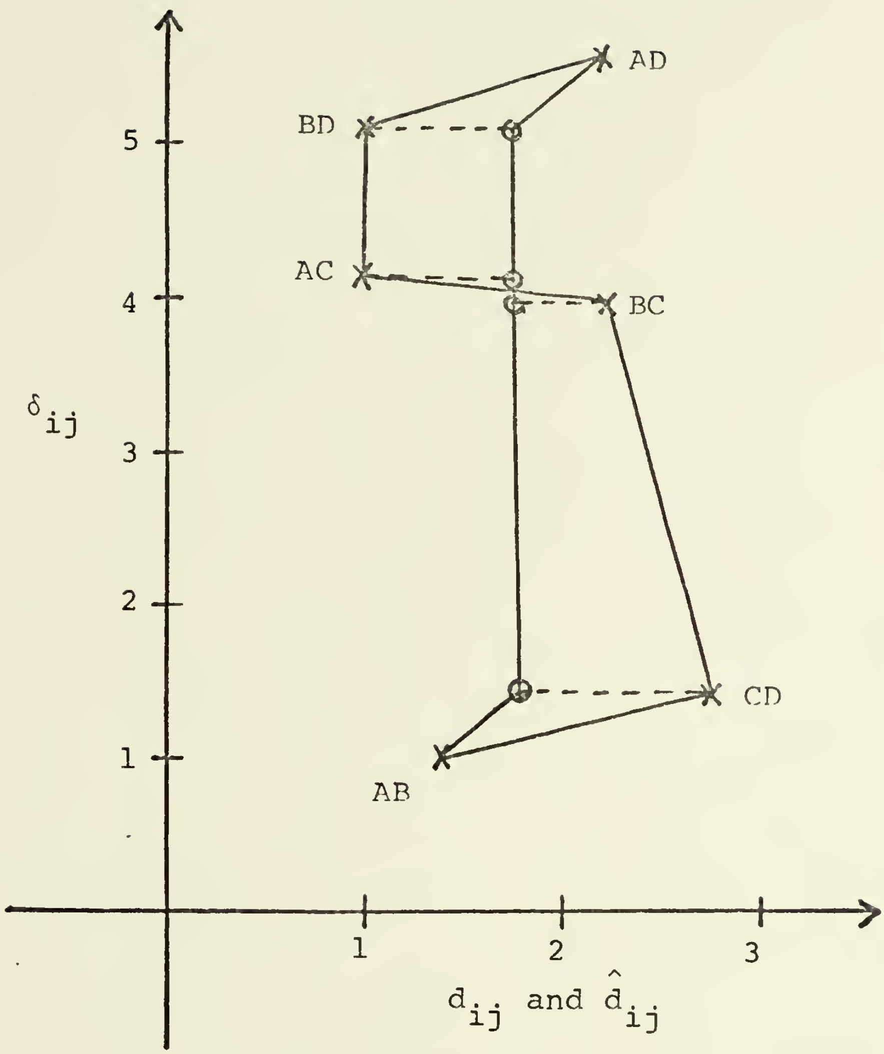
$$\doteq .11636^{\frac{1}{2}}$$

$$\doteq .34$$

Since the stress is .34, the configuration is a rather poor fit. A comparison of the "true" configuration and the initial (trial) configuration readily verifies this. It should be noted that a "true" configuration will not be known in problems of practical interest in which multi-dimensional scaling is used. The "true" configuration was used here only for illustrative purposes.

After the stress is calculated and found to be poor, the gradient, with respect to the configuration of points,

FIGURE 5



of stress and a step-size would be computed and movement along the gradient would be accomplished to reach a new configuration closer to monotonicity.

# APPENDIX B

## VOTES CONSIDERED IN THIS ANALYSIS

| Vote | Votes for 1969-1970 Sessions | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| A | Release of 100,000 short tons from the national stockpile | 47 | Committee Report | 0.356 | 58 | 32 |
| B | Continue research and development on ABM but no funds for purchase of missiles | 56 | McIntyre | 0.722 | 27 | 70 |
| C | To kill Mondale amendment on a study of nuclear-powered air-craft carriers | 71 | Pastore | 0.593 | 51 | 34 |
| D | To eliminate the prohibition of further grants of military aid to Greece | 203 | Dodd | 0.542 | 45 | 38 |
| E | To strike all funds for ABM except for personnel | 211 | Smith | 0.576 | 36 | 49 |
| F | To insist in conference that the level of appropriations not exceed that authorized by law for foreign aid and no earmarking of funds for military assistance | 243 | Mansfield | 0.686 | 48 | 22 |

APPENDIX B (Continued)

| Vote | Votes for 1969-1970 Sessions | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| G | Delete $100 million for design and definition of space shuttle for NASA in FY 1971 | 130 (1970) | Mondale | 0.659 | 29 | 56 |
| H | Nothing in the Cooper-Church amendment on SEA would preclude Pres. action to protect U.S. forces in SVN | 139 | Byrd, R. | 0.475 | 47 | 52 |
| I | To table Dole amendment to repeal Gulf of Tonkin resolution at end of 91st Congress | 147 | Fulbright | 0.817 | 15 | 67 |
| J | To table Allott amendment barring funds for Vietnam after 31 Dec. 1970 for anything but troop withdrawal and prisoner exchange | 167 | Mansfield | 0.681 | 62 | 29 |
| K | To bar funds for use in Cambodia after 30 June 1970 | 180 | Cooper Church | 0.389 | 58 | 37 |
| L | To increase funds for research and program management for NASA | 197 | Goldwater | 0.795 | 15 | 58 |
| M | To establish an independent cost accounting standards board for defense contracts by allowing the Pres. to appoint members rather than the Comptroller General | 216 | Bennett | 0.450 | 36 | 44 |

APPENDIX B (Continued)

| Vote | Votes for 1969-1970 Sessions | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| N | Delete funds for further development of the two presently deployed ABM facilities | 237 | Hughes | 0.653 | 33 | 62 |
| O | Assure that weapons systems and sub-systems are fully tested prior to production | 240 | Proxmire | 0.662 | 22 | 43 |
| P | Prohibit use of funds for military application of anti-plant chemicals | 252 | Nelson Goodell | 0.738 | 22 | 62 |
| Q | Reduce the ceiling on total authorizations for Department of Defense for FY 1971 to $66.0 billion | 256 | Proxmire Mathias | 0.575 | 31 | 42 |
| R | To pass FY 1971 Foreign Aid appropriations bill | 366 | Conference Report | 0.413 | 44 | 32 |
| S | To reduce funds for DOD public information, public affairs and public relations | 380 | Fulbright | 0.511 | 44 | 46 |
| T | To pass Supplemental Economic and Military Appropriations (for Cambodia) for 1971 | 395 | Conference Report | 0.766 | 72 | 22 |

## APPENDIX B (Continued)

| Vote | Votes for 1971 Session | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| A | Prohibit funds for U.S. troops in Europe in excess of 150,000 after 31 Dec. 1971 | 51 | Fulbright | 0.701 | 29 | 68 |
| B | To strike $85.3 million for continued development of the SST | 54 | Proxmire | 0.389 | 58 | 37 |
| C | To increase funds for pay increases for military personnel by $1.7 billion | 65 | Hughes | 0.575 | 31 | 42 |
| D | To increase funds for pay increases for military personnel, mainly lower-ranking enlisted men and lower-ranking officers | 72 | Allott | 0.346 | 51 | 27 |
| E | To bar funds for support of U.S. troops in Indo-china after 31 Dec. 1971 | 83 | McGovern Hatfield | 0.567 | 42 | 55 |
| F | To increase number of ROTC scholarships to 10,000 for each branch of the armed services per year | 88 | Hatfield | 0.524 | 40 | 44 |
| G | To direct Secretary of Defense to formulate a new salary structure to attract qualified personnel into the armed forces | 92 | Hatfield | 0.632 | 25 | 43 |

APPENDIX B (Continued)

| Vote | Votes for 1971 Session | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| H | To declare it to be U.S. policy to terminate at the earliest practicable date operations in Indo-china and to withdraw all military forces not later than nine months after date of enactment of bill | 100 | Mansfield | 0.424 | 57 | 42 |
| I | To extend the Selective Service law and raise military pay and benefits by $2.7 billion | 111 | Conference Report | 0.818 | 72 | 16 |
| J | To cancel Amchitka, Alaska nuclear blast | 138 | Gravel | 0.606 | 37 | 57 |
| K | To bar funds for the F-14 aircraft and other programs until a final environmental impact statement was filed | 200 | Nelson | 0.724 | 21 | 55 |
| L | Request the Pres. to submit an alternate defense budget for FY 1973 not to exceed $60 billion | 208 | McGovern | 0.690 | 26 | 58 |
| M | To delete $23.7 million for phase-in of production of Marine Harrier airframe in the U.S. | 211 | Saxbe | 0.500 | 40 | 40 |

APPENDIX B (Continued)

| Vote | Votes for 1971 Session | | | | Roll Call Vote | |
|---|---|---|---|---|---|---|
| | Description | CQ Number | Sponsor | Pro-Defense Vote | Yea | Nay |
| N | To allow funds for research and development but not deployment of ABM system | 214 | Hughes | 0.753 | 21 | 64 |
| O | To provide for cessation of bombing and other air attacks in Indochina | 225 | Gravel | 0.771 | 19 | 64 |
| P | To bar funds for activities of U.S. forces in South Vietnam after a given date unless national election was fair | 228 | Montoya | 0.706 | 25 | 60 |
| Q | To strike a requirement suspending foreign assistance and military sales to Greece | 250 | Allen | 0.613 | 49 | 31 |
| R | To reduce funds for military grant aid | 255 | Church | 0.365 | 47 | 27 |
| S | To reduce ceiling on aid to Cambodia from $341 million to $263.5 million | 278 | Nelson | 0.517 | 43 | 46 |
| T | To prohibit use of funds after 15 June 1972 to support U.S. troops in Europe in excess of 250,000 | 361 | Appropriations Committee Amendment | 0.581 | 39 | 54 |

# APPENDIX C

ACTUAL AND PREDICTED VALUES FOR 1971
PRO-DEFENSE PROPORTION OF VOTE

| Vote | Actual | Predicted |
|---|---|---|
| A | 0.701 | 0.677 |
| B | 0.389 | 0.396 |
| C | 0.576 | 0.564 |
| D | 0.346 | 0.436 |
| E | 0.567 | 0.603 |
| F | 0.524 | 0.602 |
| G | 0.632 | 0.633 |
| H | 0.424 | 0.531 |
| I | 0.818 | 0.762 |
| J | 0.606 | 0.626 |
| K | 0.724 | 0.666 |
| L | 0.690 | 0.649 |
| M | 0.500 | 0.533 |
| N | 0.753 | 0.688 |
| O | 0.771 | 0.726 |
| P | 0.706 | 0.686 |
| Q | 0.613 | 0.622 |
| R | 0.365 | 0.449 |
| S | 0.517 | 0.585 |
| T | 0.581 | 0.627 |

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| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) Charles Michael Rankin; CAPT, U.S. Army | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940 | | 12. REPORT DATE September 1973 |
| | | 13. NUMBER OF PAGES 91 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Postgraduate School Monterey, California 93940 | | 15. SECURITY CLASS. (of this report) Unclassified |
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A somewhat new approach to the analysis of defense issues in the United States Senate has been developed in this thesis. The Relative Agreement statistic of Brams and O'Leary was used

to obtain similarity observations between twenty Senate defense votes for both 1969-1970 and 1971. These similarity observations were then used as input data to KYST, a multidimensional scaling computer program. The scaling solutions resulting from KYST showed that the most important dimensions in explaining pro-defense voting were non-partisan/partisan and foreign policy/domestic policy. By using the pro-defense proportion of the vote as the dependent variable and coordinates from the two-dimensional solution as the independent variables, a regression model was obtained for predicting pro-defense vote. Within the time period under consideration, an examination of regression coefficients revealed that future arguments for defense programs in the Senate should emphasize foreign policy and non-partisan aspects of such programs while de-emphasizing domestic implications and partisan aspects.

Thesis 146410
R214 Rankin
c.1 Investigation of dimensions of perception of United States Senators on defense-oriented roll-call votes.